Subterranean Biology 13: 45–54 (2014)
doi: 10.3897/subtbiol.13.6719
www.pensoft.net/journals/subtbiol

RESEARCH ARTICLE

A peer-reviewed open-access journal
Subterranean Biology
Published by The International Society for Subterranean Biology

# Measurements of the diet in two species of *Troglophilus* Krauss, 1879 cave crickets from Italian subterranean habitats (Orthoptera, Rhaphidophoridae)

Claudio Di Russo[1], Mauro Rampini[1], Leonardo Latella[2], Marina Cobolli[1]

**1** *Dipartimento di Biologia e Biotecnologie "Charles Darwin", Università degli Studi di Roma "Sapienza", Viale dell'Università 32, I-00185 Roma-Italy* **2** *Museo Civico di Storia Naturale di Verona, Lungadige Porta Vittoria 9, I-37129 Verona - Italy*

Corresponding author: *Leonardo Latella* (leonardo.latella@comune.verona.it)

Academic editor: *O. Moldovan* | Received 29 November 2013 | Accepted 26 February 2014 | Published 18 March 2014

**Citation:** Di Russo C, Rampini M, Latella L, Cobolli M (2014) Measurements of the diet in two species of *Troglophilus* Krauss, 1879 cave crickets from Italian subterranean habitats (Orthoptera, Rhaphidophoridae). Subterranean Biology 13: 45–54. doi: 10.3897/subtbiol.13.6719

### Abstract

The diet of two populations of cave crickets, *Troglophilus cavicola* from Veneto, northern Italy and *Troglophilus andreinii* from Apulia, southern Italy, were studied by analyzing faecal and gut contents. The results obtained document different food preferences in these two species. In the *Troglophilus cavicola* population arthropod remains were dominant in the diet, whereas in the *T. andreinii* population vegetables (green and fibres) were the more abundant food category. Furthermore, study of the overlap of food resource exploitation among age and sex sub-samples seems to indicate a separation of diet among the young instars and other age classes of the populations. Differences in diet between males and females were observed only in the population of *T. andreinii*.

### Keywords

*Troglophilus,* Troglophilinae, Rhaphidophoridae, trophic niche, cave crickets, feeding habits, Italy

## Introduction

In general, the feeding habits of Rhaphidophoridae cave crickets are considered to be omnivorous–saprophagous (Chopard 1938). Early observations on the genus *Dolichopoda* Bolivar, 1880 indicated the exploitation of vegetable matter and arthropod remains (Monti 1902). A similar diet has also been described for other Rhaphidophoridae

(Macropathinae),such as species of the Australian genera *Gymnoplectron* Hutton, 1897, *Pallidoplectron* Richards, 1958, *Micropathus* Richards, 1964 and *Pallidotettix* Richards, 1964 (Richards 1962; 1968; 1970), *Spelaeiacris tabulae* Peringuey, 1916 from Wynberg cave, Capetown, SouthAfrica (Carchini et al. 1991) and of the Patagonian species *Heteromallus cavicola* Ander, 1932 ( Di Russo et al. 1996). Furthermore, other data indicating a omnivorous diet are available for some species of the North American genera *Hadenoecus* Scudder, 1863 and *Ceuthophilus* Provancher, 1876 (Hubbel and Norton 1978, Lavoie et al. 2007).

An example of predatory habits was reported by Chopard (1959) for *Rhaphidophora oophaga* Chopard, 1959, of which some individuals were observed to eat eggs of the Black-nest Swiftlet *Collocalia maxima* Hume, 1878 in the Subis cave, Sarawak, Malaysia.

In a more recent study, conducted on some Italian populations of the genus *Dolichopoda*, the trophic niche has been quantitatively described (De Pasquale et al. 1995). In this case, differences in the exploitation of resources in relation to the age of the cave, climatic stability of the habitat, type and amount of trophic resources and the diversity of the biotic community were established. Concerning species and populations of the genus *Troglophilus* Krauss, 1879, very little is known about their feeding habits. Early, fragmentary observations suggested an omnivorous diet for *Troglophilus* (Remy 1931, Avesani et al. 2009). Semi-quantitative analysis confirming this type of diet are available only for some populations of *Troglophilus cavicola* (Kollar, 1833) from Slovenian cave habitats (Novak and Kustor 1983).

The present study is part of a more extensive research project investigating the population ecology of the Italian species of *Troglophilus* cave crickets (Di Russo et al. 2008). In particular, the results on trophic resource exploitation of two populations belonging to *Troglophilus cavicola* and *T. andreinii* Capra, 1927 are reported and discussed in relation to their population ecology.

## Systematics and ecological background

The genus *Troglophilus* has a wide east-mediterranean distribution, with 15 species occurring from Austria and Italian pre-Alps to the Balkan-Anatolian region (Eades et al. 2013). The large number of species present in the latter area suggests a primary centre of dispersal located in the eastern paleo-Mediterranean (Ruffo 1955). Recently, some studies on the population ecology of *Troglophilus* have been carried out, but information on this topic is very fragmentary and insufficient. In particular, these studies, conducted on some populations of *T. cavicola* and *T. neglectus* Krauss, 1879 from Slovenia caves, allowed for only a partial description of their life cycle as completed in two years. Furthermore, the occurrence of two seasonal ecophases was established: one hypogean in winter and one epigean in summer. According to these observations, the crickets use the caves only as winter shelter, and defect the caves in summer to feed and to reproduce in the epigean habitat (Novak and Kustor 1983; Pehani et al. 1997). Beginning in 2000, similar studies were also carried out in some Italian populations of *T.*

*cavicola* and *T. neglectus* from the Lessini Mountains (Latella et al. 2002; Avesani et al. 2009) and of *T. andreinii* from Apulia (Di Russo and Rampini 2005). In these studies, strong summer reductions of population sizes in caves were reported, confirming the existence of the two ecophases in the Italian populations just as in those from Slovenia. However, although summer population reductions occur in *T. andreinii,* these appear to be less marked and involve a very short time span.

## Materials and methods

This study is based on the analysis of 225 faecal and gut content samples collected periodically from August 2004 to October 2005. In *T. cavicola* we analysed 76 samples (56 feculae and 20 guts) from Covoli di Velo cave in the Lessini Mountains (Grotta Inferiore dei covoli di Velo 44 V/VR, altitude 878 m a.s.l., Velo Veronese, Verona). For *T. andreinii*, an endemic species of Apulia, we analysed 149 samples (98 faeces and 51 guts) from Tranese cave [Grotta della Masseria Tranese 486 Pu/BA, altitude 330 m a.s.l., Contrada Tranese, Putignano, Bari]. Sub-samples from individuals of different sex and developmental stages (adult, nymphs and young) were analyzed. In particular for *T. cavicola*, we utilized 24 adults, 26 nymphs and 26 young instars, while for *T. andreinii* 52 adults, 47 nymphs and 50 young instars have been used. The distinction in these three age classes is based on the maturation of sexual characters for the adults and the hind tibia lenght for the other two classes (Nymph = hind tibia included between 15 and 21 mm; Young instar = hind tibia < 15 mm). Fresh faeces were collected from individuals put in a plastic box separately for 24 hours without any food supply. Gut samples were obtained by dissection of fresh individuals. Both faecal and gut pellets were conserved in alchool 70%. The comparison among gut and faecal samples does not reveal any differences in their content, permitting us to pool data obtained by these two types of source.

Feacal and gut contents were spread in Euparal on 24×24 mm slides and examined with an optical microscope (Leica M.Z.12.5). The material analysed was classified into three categories: green vegetables, vegetable fibres and arthropod remains. In order to obtain quantitative estimates, we used a 576 mm$^2$ grid and the food items scored were recorded as proportion of the total area observed. The niche breadth was cumulatively evaluated, for each periodical sub-sample, by the Gini-Simpson index (Gini 1912):

$$B = \mathbf{1- \Sigma p_i^2}$$

where $p_i$ = the proportion of the ith item in the faecal or in the gut content.

The overlap in the resource exploitation among age and sex sub-samples was investigated by the Morisita index (1959) as modified by Horn (1966):

$$M_o = 2 \mathbf{\Sigma\, p_{ij}\, p_{ik} / \Sigma\, p^2_{ij} + \Sigma p^2_{ik}}$$

where $p_{ij}$ and $p_{ik}$ are the proportions of ith item utilization by the jth and kth populations.

The examined specimens and slides are deposited in the collections of the Museo Civico di Storia Naturale of Verona and of the Dipartimento di Biologia e Biotecnologie “Charles Darwin”, Università degli Studi di Roma “Sapienza.

## Results

### Annual diet comparison between the two species

The percentages of utilization of the food resources are compared in the two species over the entire year. For the *Troglophilus cavicola* population (Covoli di Velo), we observed the dominance of arthropod remains in the diet (69.44%); by contrast, in the *T. andreinii* population (Tranese cave), vegetables (green and fibres) were the more abundant food category, reaching about 92%.

Fig. 1 reports comparisons among periodical samples of the two populations. In this case, differences in the exploitation of food resources in different periods of the year are evident. Particularly in the *T. cavicola* population, there is a clear increase of vegetable fibres in summer samples and a complete shift to the exploitation of arthropods remains (over 98%) in winter. By contrast, in the *T. andreinii* population, the diet is mainly based throughout the year of vegetables (never below 80%), with a small increase of fibres and arthropods in autumn and winter.

These findings are confirmed by the trophic niche breadth analysis conducted on the periodical samples of the two populations. In Fig. 2 seasonal values of the Gini- Simpson index for the two population are compared, showing an opposite trend of variation. In particular, in *T. cavicola*, which has a mean value of the index of 0.44, the highest values of the niche breadth are found in summer and spring, where all the three food categories were exploited. The lowest values occur in winter, where mainly arthropod remains were used. By contrast, in *T. andreinii* the mean values of the Gini-Simpson index were significantly lower (0.16), with a moderate peak in winter corresponding to a more balanced exploitation of the three resources.

### Overlap of food resource exploitation among age and sex sub-samples

Fig. 3 compares the annual diet of different age sub-samples. In both populations young individuals show a significantly different exploitation of resources in comparison to those of nymphs and adults. In particular, these differences are greater in the *Troglophilus cavicola* population than in that of *Troglophilus andreinii*. The diet of young instars of *T. cavicola* is mainly based on vegetables (fibres+vegetable matter = 69%), whereas arthropods are dominant in nymphs and adults. In the *T. andreinii* population the diet of the three age classes appears more balanced, with a little difference in the young instars where a moderate increase of arthropods occurs. These results can be described by the overlap analysis using the Morisita index (Fig. 4). The dendrograms performed using Euclidean distances based on matrices of this index clearly show a separation of the diet of the young instars from that of nymphs and adults.

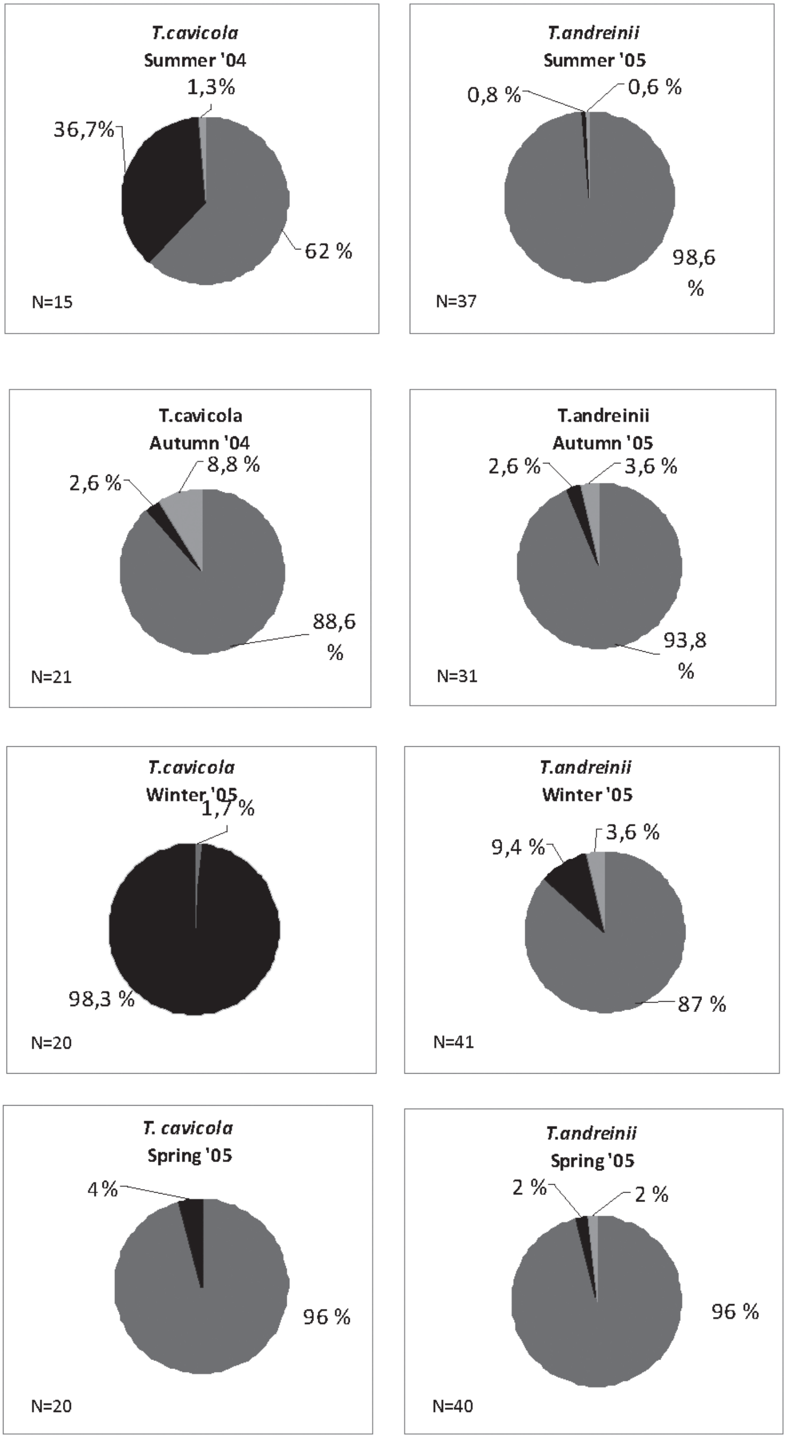


**Figure 1.** Seasonal comparison of food resource exploitation among cumulate samples of *T. cavicola* and *T. andreinii*. Grey: green vegetables; light grey: fibres; black: arthropod remains.

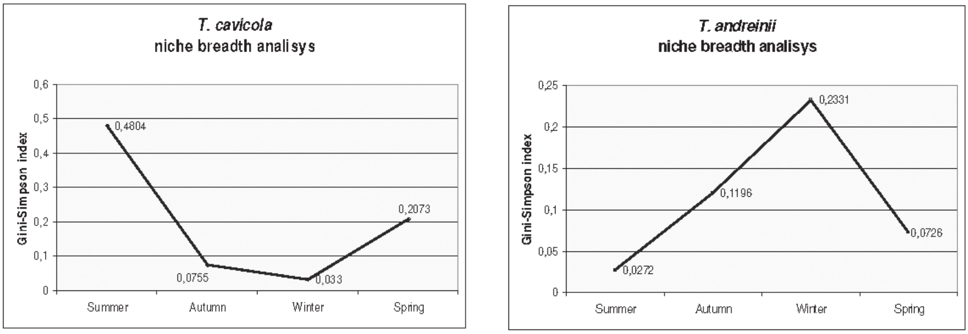


**Figure 2.** Comparison of seasonal niche breadth in *T. cavicola* and *T. andreinii* populations

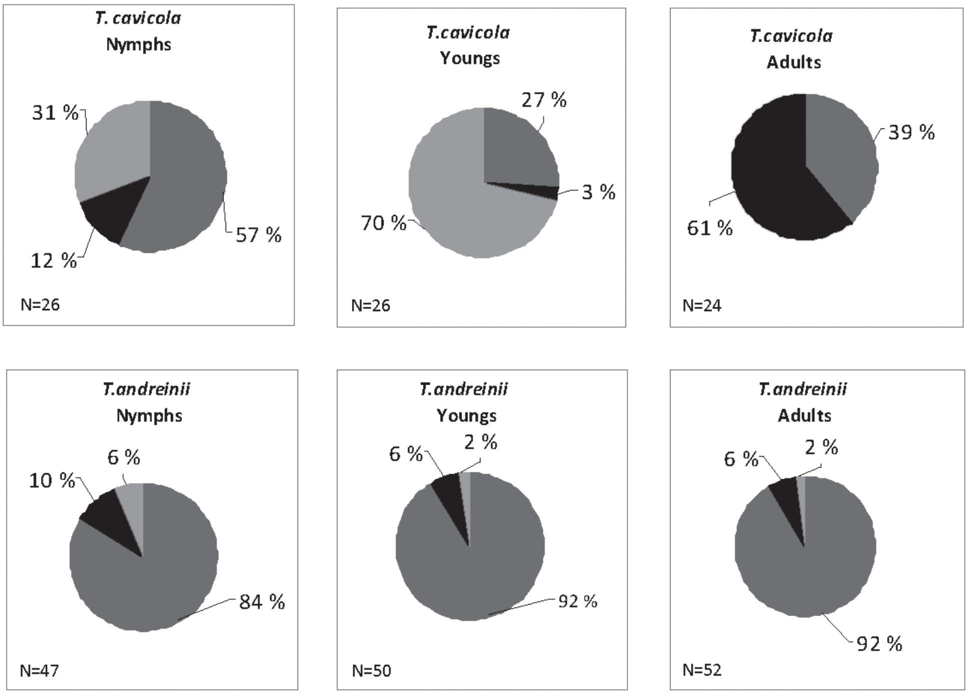


**Figure 3.** Comparison of the diet among age sub-samples (Young instars, Nymphs and Adults) of *T. cavicola* and T. *andreinii*. Grey: green vegetables; light grey: fibres; black: arthropod remains.

Differences in diet between males and females have been observed only in the Tranese population and only in a periodical sample. In this case, female niche breadth in autumn has a value of the Gini-Simpson index higher in comparison with that of males (i.e. 0.336 vs 0.04). This result seems related to the exploitation in this period of a consistent percentage of arthropod remains by females (Fig.5).

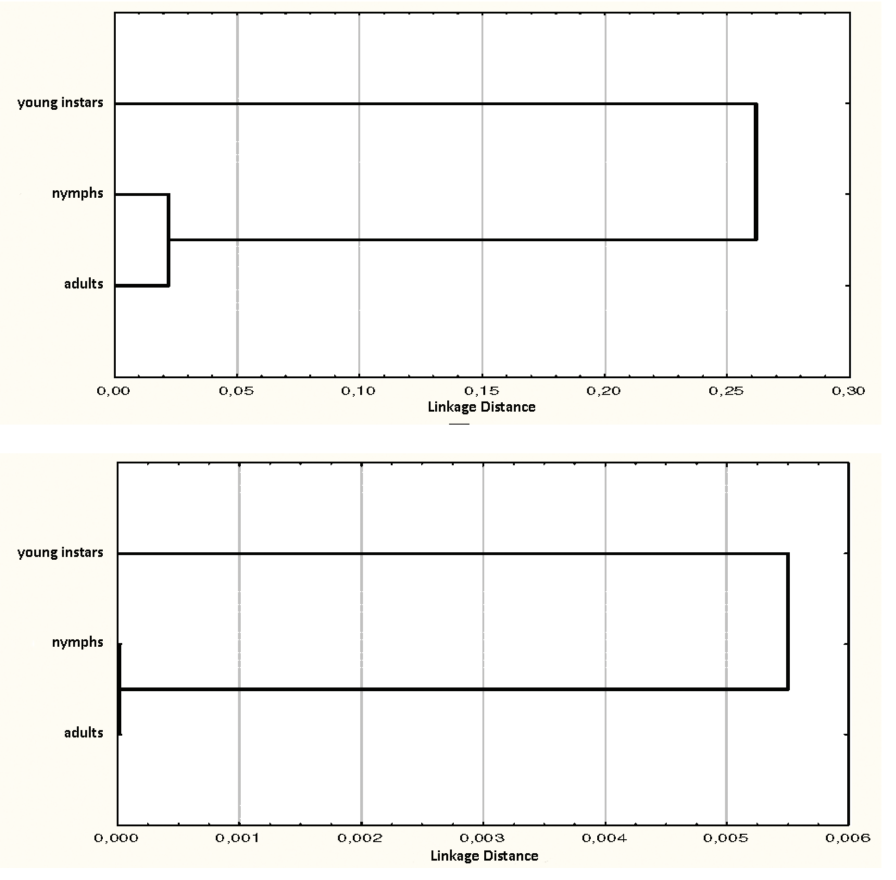


**Figure 4.** Overlap analysis of food resource exploitation conducted in individuals of different age (young instars, nymphs and adults). The dendrograms were performed using euclidean distances based on the Morisita-Horn index matrices. (a: *T. cavicola*, b: *T. andreinii*).

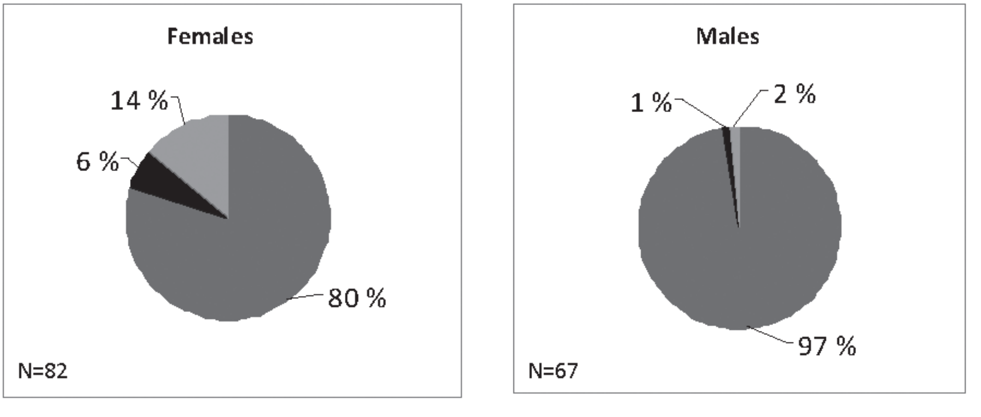


**Figure 5.** Comparison of the autumnal diet between female and male sub-samples of *T. andreinii*. Grey: green vegetables; light grey: fibres; black: arthropod remains.

## Discussion

Remarkable differences in exploitation of these resources can be observed comparing the diet of the two populations herein studied. In particular, in the *T. cavicola* population we observed a diet mainly based on arthropod remains (69%). This finding is chiefly due to the exploitation inside the cave of this type of resource in winter during the strictly hypogean ecophase. In this case, individuals at Covoli di Velo were forced into the cave by the hard climate typical of pre-alpine winter. The large amount of arthropods in this unfavourable winter period can be related to the high availability of this resource inside the Covoli di Velo, where a complex cave biocenosis is present (Caoduro et al. 1994, Zorzin et al. 2000). By contrast, in the *T. andreinii* population, located in southern Italy, the abundance of vegetable matter (green and fibres) appears constant throughout the year suggesting a continuous exploitation of vegetables outside the cave habitats. In the Tranese cave, due to the typical dry climate of the Mediterranean regions, all phases of the life cycle are completed in the hypogean habitat, as suggested by the observations of mating and hatching of eggs in the cave, with crickets moving outside the cave only for daily food. This result is in agreement with the reduction in the Tranese population of a strict division of the population phenology in two ecophases as shown by the occurrence in summer of a remarkable number of individuals in the cave.

The analysis of niche breadth seems to confirm this result: lower values of Gini-Simpson index in *T. cavicola* indicating a dominance of a single type of resource (arthropods), are observed only in winter; in the same period, the Tranese population shows an higher value of this index, suggesting a diet more balanced among the available resources outside and inside the cave.

## Conclusions

On the whole, as described for other Rhaphidophoridae species (Di Russo and Sbordoni 1998), we can confirm for *Troglophilus* populations an omnivorous diet based on vegetable matter and arthropod remains.

The study of overlap resource exploitation seems to indicate a separation of diet among young instars and the other age classes of the populations (nymphs and adults). This finding is confirmed by the Morisita–Horn index and is more evident in the *T. cavicola* populations. As found in the Italian *Dolichopoda* populations (De Pasquale et al. 1995), differences in niche during the life cycle can affect population dynamics and reduce competition for food among individuals of different ages (Polis 1984, Ebenman 1987). Differences in diet between males and females have been observed only in the Tranese population. In this case, the increase of female niche breadth in autumn is related to the exploitation of a consistent percentage of arthropod remains. This period of the year corresponds to the time of reproduction of the population (Di Russo et al. 2008); therefore, as found in other arthropods (Coll and Guershon 2002), increasing the animal component in the diet could be interpreted as a protein requirement for maturation of eggs.

## Acknowledgements

We thanks all of the individuals that collaborated with the researchers, and we are especially indebted to Federica De Bellis, Enrico Mezzanotte and Marco Sommaro for the help in the collection of the cricket samples and processing of our data and Roberta Salmaso for the assemblage of the pictures.

We are also grateful to James Tyler for the language revision.

## References

Avesani D, Poiesi M, Rampini M, Latella L, Di Russo C, Cobolli M (2009) Biologia ed ecologia di *Troglophilus cavicola* (Kollar, 1833) della Grotta Damati sui Monti Lessini Veronesi (Orthoptera, Rhaphidophoridae). Bollettino del Museo Civico di Storia Naturale di Verona, Botanica Zoologia 33: 113–120.

Caoduro G, Osella G, Ruffo S (1994) La fauna cavernicola della regione veronese. Memorie del Museo Civico di Storia Naturale di Verona (II serie), sezione Scienze della Vita (A: Biologica) 11: 1–144.

Carchini G, Di Russo C, Rampini M (1991) Observation on the biology of *Spelaeiacris tabulae* Peringuey (Orthoptera, Rhaphidophoridae) from the Wynberg cave (Capetown, South Africa). International Journal of Speleology 20: 47–55. doi: 10.5038/1827-806X.20.1.5

Chopard L (1938) La Biologie des Orthoptères. Encyclopédie Entomologique 20, Paul Lechevalier, Paris, 541 pp.

Chopard L (1959) Sur les Moeurs d'un *Rhaphidophora* cavernicole. Annales de Spéléologie 14(1–2): 181–184.

Coll M, Guershon M (2002) Omnivory in terrestrial Arthropods: mixing plant and prey diets. Annual Review of Entomology 47: 267–297. doi: 10.1146/annurev.ento.47.091201.145209

De Pasquale L, Cesaroni D, Di Russo C, Sbordoni V (1995) Trophic niche, age structure and seasonality in *Dolichopoda* cave crickets. Ecography 18: 217–224. doi: 10.1111/j.1600-0587.1995.tb00124.x

Di Russo C, De Pasquale L, Rampini M (1996) On the biology of two Patagonian Rhaphidophoridae (Orthoptera): *Heteromallus cavicola* Ander, 1932 and *Udenus w-nigrum* Brunner, 1898. Anales del Instituto de la Patagonia, Serie Ciencias Naturales, Punta Arenas (Chile) 24: 105–116.

Di Russo C, Sbordoni V (1998) Orthoptera Gryllacridoidea. Encyclopaedia Biospeologica. Société de Biospéologie, Moulis-Bucarest, vol. II : 979–988.

Di Russo C, Rampini M (2005) Primi dati sull'ecologia di popolazione di *Troglophilus andreinii* (Orth.: Rhaphidophoridae) della grotta Tranese di Putignano (Bari). Grotte e Dintorni (5) 9: 61–68.

Di Russo C, Rampini M, Latella L, Cobolli M (2008) Studi di biologia di popolazione in *Troglophilus* delle grotte italiane (Orthoptera, Rhaphidophoridae). Atti del XX Congresso Nazionale di Speleologia, Iglesias 27–30 aprile 2007- Memorie dell'Istituto Italiano di Speleologia, s.2, 21: 96–102.

Ebenman B (1987) Niche differences between age classes and intraspecific competition in age-structured populations. Journal of Theorethical Biology 124: 25–33. doi: 10.1016/S0022-5193(87)80249-7

Eades DC, Otte D, Cigliano MM, Braun H (2013) Orthoptera Species File Online. Version 5.0/5.0.

Gini C (1912) Variabilità e mutabilità. Contributo allo studio delle distribuzioni e delle relazioni statistiche. C. Cuppini, Bologna, 158 pp.

Horn HS (1966) Measurements of "overlap" in comparative ecological studies. American Naturalist 100: 419–424. doi: 10.1086/282436

Hubbel TH, Norton RM (1978) The systematics and biology of the cave-crickets of the North American tribe Hadenoecini (Orthoptera Saltatoria: Ensifera: Rhaphidophoridae: Dolichopodinae). Misc. Publ. Museum of Zoology, University of Michigan 156: 1–124.

Latella L, Mezzanotte E, Rampini M (2002) Ricerche sugli Ortotteri cavernicoli dei Covoli di Velo. Quaderno Culturale – La Lessina Ieri oggi domani 25: 113–116.

Lavoie KH, Helf KL, Poulson TL (2007) The biology and ecology of North American cave crickets. Journal of Cave and Karst Studies 69: 114–134.

Monti R (1902) Contributo alla conoscenza delle *Dolichopoda geniculata* (O. G. Costa). Rendiconti del Regio Istituto Lombardo di Scienze e Lettere, Serie II, 35: 3–24 +1 tav.

Morisita M (1959) Measuring of interspecific association and similarity between communities. Memoirs of the Faculty of Science, Kyushu University, Series E (Biology) 3: 65–80.

Novak T, Kustor V (1983) On *Troglophilus* (Rhaphidophoridae, Saltatoria) from North Slovenia (YU). Memoires de Biospéologie 10: 127–137.

Pehani S, Virant-Doberlet M, Jeram S (1997) The life cycle of the cave cricket *Troglophilus neglectus* Krauss with note on *T. cavicola* (Kollar) (Orthoptera: Rhaphidophoridae). The Entomologist 116 (3): 224–238.

Polis GA (1984) Age structure component of niche width and intraspecific resource partitioning: can age groups function as ecological species. The American Naturalist 123: 541–564. doi: 10.1086/284221

Remy P (1931) Observations sur les Moeurs de quelques Orthoptères cavernicoles. Annales des Sciences Naturelles Zoologie et Biologie Animale 14 (10): 263–274.

Richards AM (1962) Feeding Behaviour and Enemies of Rhaphidophoridae (Orthoptera) from Waitomo Caves, New Zealand. Transactions Royal Society of N. Z., Zoology, 2 (15): 121–129.

Richards AM (1968) Notes on the Biology of two Species of Rhaphidophoridae (Orthoptera) in Tasmania. Proceedings of the Linnean Society of New South Wales 92 (3): 273–278.

Richards AM (1970) Observations on the biology of *Pallidotettix nullarborensis* Richards (Rhaphidophoridae: Orthoptera) from the Nullarbor Plain. Proceedings of the Linnean Society of New South Wales 94: 195–206.

Ruffo S (1955) Le attuali conoscenze della fauna cavernicola della regione pugliese. Memorie di Biogeografia Adriatica 3: 1–143.

Zorzin R, Latella L, Rossi M (2000) Le ricerche scientifiche del Museo Civico di Storia Naturale di Verona presso i Covoli di Velo. Quaderno Culturale-La Lessinia ieri oggi e domani 23: 2936.